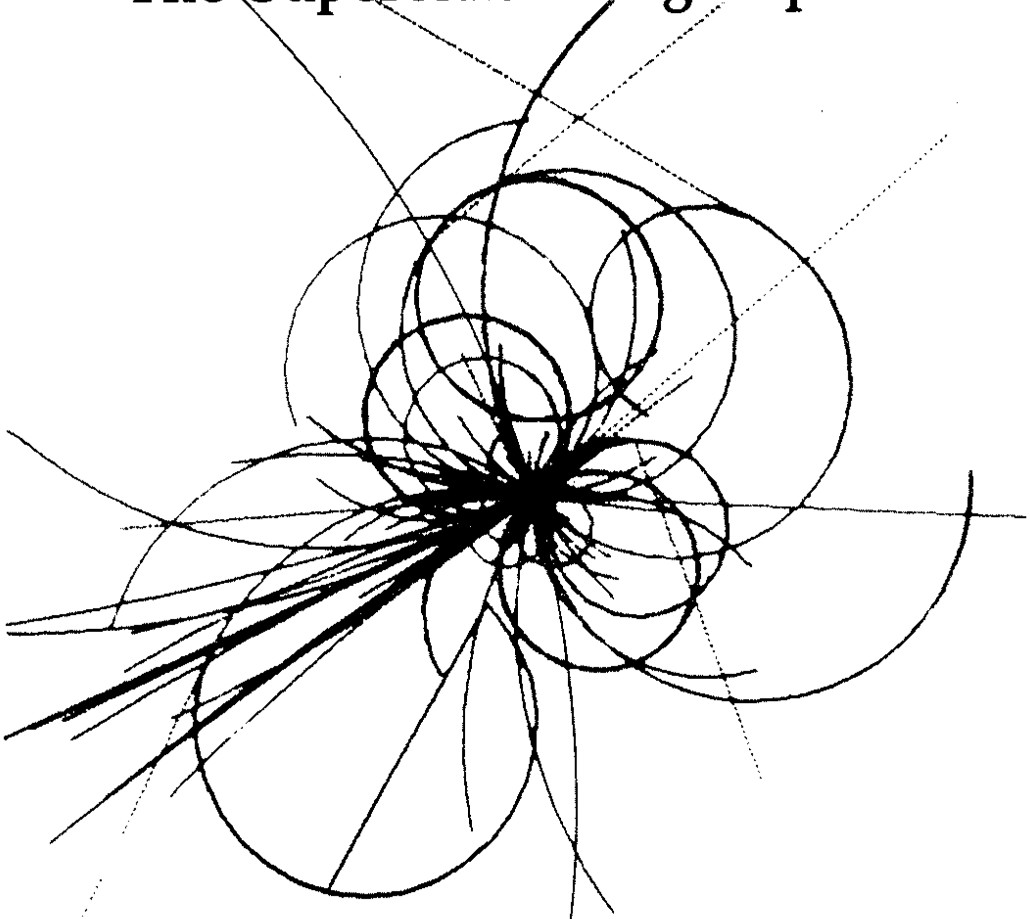
SSC-169

The Superconducting Super Collider



MILLION REVOLUTION ACCELERATOR BEAM INSTRUMENT FOR LOGGING AND EVALUATION

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MILLION REVOLUTION ACCELERATOR BEAM INSTRUMENT FOR LOGGING AND EVALUATION

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ABSTRACT

A data acquisition and analysis instrument for the processing of accelerator beam postition monitor (BPM) signals has been assembled and used preliminarily for beam diagnosis of the Fermilab accelerators. Up to eight BPM (or other analogue) channels are digitised and transmitted to an acquisition Sun workstation and from there both to a monitor workstation and a workstation for off-line (but immediate) data analysis. A coherent data description format permits fast data object transfers to and from memory, disk and tape, across the Sun ethernet. This has helped the development of both general purpose and experiment-specific data anlaysis, presentation and control tools. Flexible software permits immediate graphical display in both time and frequency domains. The instrument acts simultaneously as a digital oscilloscope, as a network analyser and as a correlating, noise-reducing spectrum analyser.

1. Introduction

The immediate motivation for the construction of a many-turn beam data acquisition and analysis system was the E778 experiment at the Fermilab tevatron [1] , intended to increase the understanding of non-linear effects on betatron motion which have important consequences for the design of the SSC. The second stage of this experiment, carried out in February 1988, required more and higher precision data than the first run, and the limited machine time available implied highly efficient data taking, monitoring and logging if the ambitious schedule was to be completed.

In the longer term, commisioning and operation of the SSC will require powerful and flexible tools to control the accelerator from the physics of the beam, very possibly through feedback loops closed by software [2] . The E778 experiment provided an ideal opportunity to test some approaches to such analysis and control problems.

The availabilty of high performance industry hardware and low-level software standards make the design and construction of the system possible within time and financial constraints. Higher level software - closer to application level - is more problematic. A serious attempt has been made to construct general purpose tools for the E778 experiment which will transfer to future SSC tasks as simply as possible. These rely on emerging low-level software standards where possible and suggest general techniques where no appropriate standard is evident.

2. Hardware

A block diagram of the hardware configuration is shown in figure 1.

Normal tevatron beam position pickups are used, the signals being treated by two front end electronic circuits and digitised in parallel. One, the standard Fermilab BPM front end, gives direct horizontal, vertical and intensity signals. The other is a purpose built peak sensing circuit which gives less noisy signals from the separate plates of two horizontal and one vertical pickup.

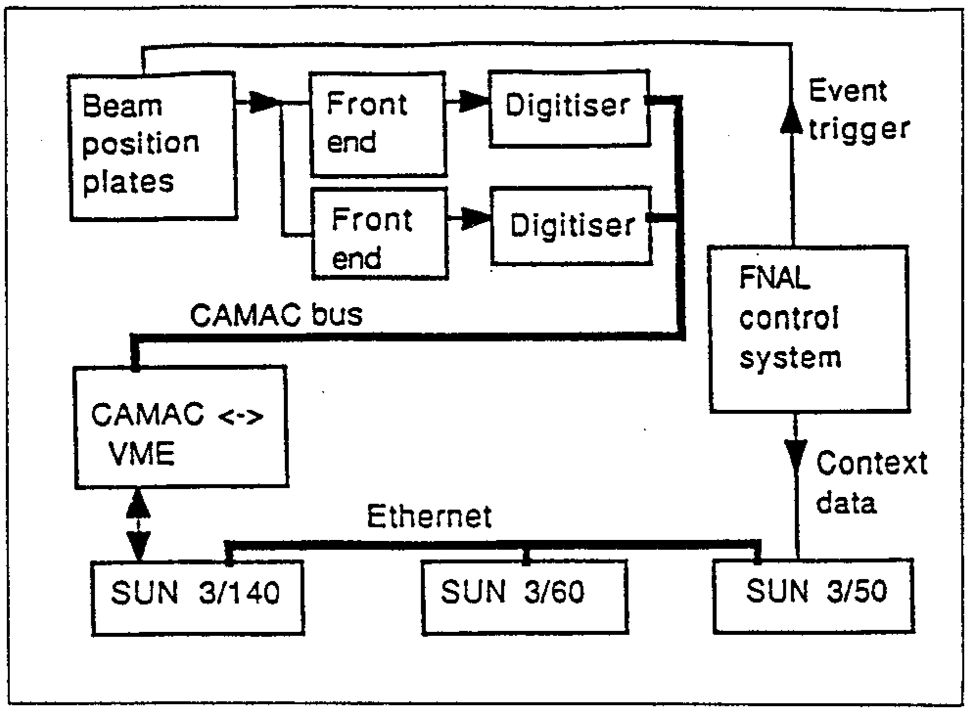

figure 1

The signals are digitised with two LeCroy 6810 5-Mhz, 12-bit transient digitisers, each with .5 Megasamples of onboard memory. The two pairs of horizontal peak-sensor signals are combined in the differential inputs of the digitiser to give direct position measurements, whereas the vertical signals are separately monitored to give both position and intensity after external data treatment.

The sampling clock for digitisation is the tevatron beam-synchronised revolution frequency clock. The digitisers, once armed, sample continuously until an external 'freeze data' signal arrives. This is derived from a standard accelerator event, typically linked to the event which fires the beam pinger or triggers the rf frequency modulation for chromaticity measurments.

The camac-based LeCroy modules are controlled by a Sun 3/140 workstation via the Sun's VME backplane and a CES CBD/8210 camac branch driver. Control and data flow to the two control room workstations are through the Suns' ethernet links.

Context information - kicker voltages, tune settings, sextupole currents and so on - is fed to the system from the tevatron control system through a serial link.

Data, context information and run commentaries are logged to a disk fifo buffer and to cartridge tape for long term storage.

3. Software

An idealisation of the E778 run is used to illustrate the required abilities of the instrument. The analysis suggests the presence of two sorts of information moving around the system, which are labelled control messages and data.

Figure 2 represents a number of actions performed (not necessarily by computer) during the experiment. Solid lines represent control messages linking the processes : the model here shows a central scheduler arbitrating these control links, although other models are certainly possible. Dotted lines show the routes that data follows

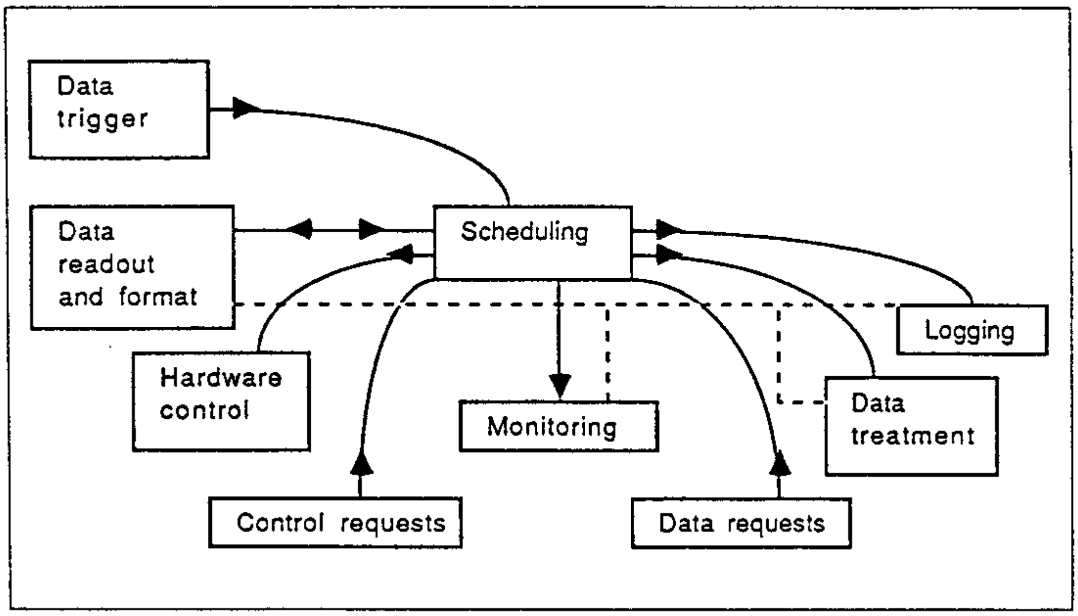

figure 2

In the early stages of the experiment the control and data requests and the scheduling are done by the experimenters and operations crew. As the experimental conditions are stabilised, it is desirable that scheduling becomes computer controlled, freeing the experimenters to concentrate on data monitoring and interpretation. Finally, to become operational tools - for tune and chromaticity feedback, for instance - robust and sophisticated control paths must be implemented. An important part of the software design is to ease this development from experiment to operation.

As a basis of the process modularity implied by the model of figure 2, a coherent data description format is used for all data moved between programs. Always present with the data, this description contains

— data name

— data typing

— data size

— timestamp

and, if required

— offset and scaling factors

— units

— limits

— presentation information

The example below shows the description created at the time the camac is read which accompanies this raw data wherever it goes. Firstly we have the description of how the data are formatted, (translated for human beings to read: it is stored in binary):

---

dataset 'camac station 9' 4 user objects created Thu Feb 25 00:28:10 1988

---

1 :'H 42D:acq 1' 65536 16-bit integers(68k byte order)
2 :'H 44D:acq 1' 65536 16-bit integers(68k byte order)
3 :'V 45A:acq 1' 65536 16-bit integers(68k byte order)
4 :'V 45Z:acq 1' 65536 16-bit integers(68k byte order)
5 :'plot struct' 4 structure(s) of 216 bytes

Here, '68k byte order' means that the internal byte ordering is that of the Motorola 68000 series of microprocessors (rather than Vax, for instance). Additionally, we have a description of what the data represents:

dataset 'camac station 9' created Thu Feb 25 00:28:10 1988
1 :'H 42D:acq 1'
X: 0 to 65536 turns, scale 1.0, offset 0
Y: 0 to 4096 100 microV, scale 1.0, offset -2048

and so on for the other four objects. Each data object corresponds to one data partition from one channel of the digitiser so the full range of the digitiser's capabilities - from one 500000-sample acquisition of a single channel to 128 1024-sample acquisitions of all four channels - can be reflected by the dataset structure. Changes to this structure, or to gains and so on, may be made online without requiring a database or logging file to be informed.

These description data allow binary data to be transferred around a heterogenous computer network without reference to the program code which originally wrote them, and the creation of general purpose tools at the process rather than subroutine level. To date, these include processes to give interactive graphical data representation, FFT and correlation operations, data listing and reformatting and simple array manipulations such as numerical compression and integration.

Implementation of control flow is as yet ad hoc, although based on the sophisticated remote procedure call and external data representation libraries provided by Sun microsystems.

The above software is written almost entirely in C. It is necessary to support Fortran code for the more specific experimental analysis jobs, and although Fortran's world-view causes some difficulties in interfacing to these general tools, existing Fortran programs have been fitted into the structure with very little disturbance.

4. Performance

The system performed well during the E778 run of February 1988, both as an instrument for online accelerator physics study and as a production data gathering and monitoring system. Further main ring and tevatron studies are planned.

A sample of the power of the system is shown in figure 3. This is taken from a screen dump of the monitor workstation, and gives four views on two of the eight channels of turn-by-turn data being recorded - in this case for 65536 turns or almost 1.4 seconds.

Strong non-linearities in the tevatron lattice from special sextupoles have created stable transverse resonance islands. The top two plots show the horizontal beam position at two different locations. The beam is kicked horizontally about 4mm at the left of the plots, but instead of decohering completely, a fraction of the beam has become locked in these resonance islands at a tune of .400. At lower left, the typical five-fold symmetry of this resonance remains clear more than 1 second after the kick.

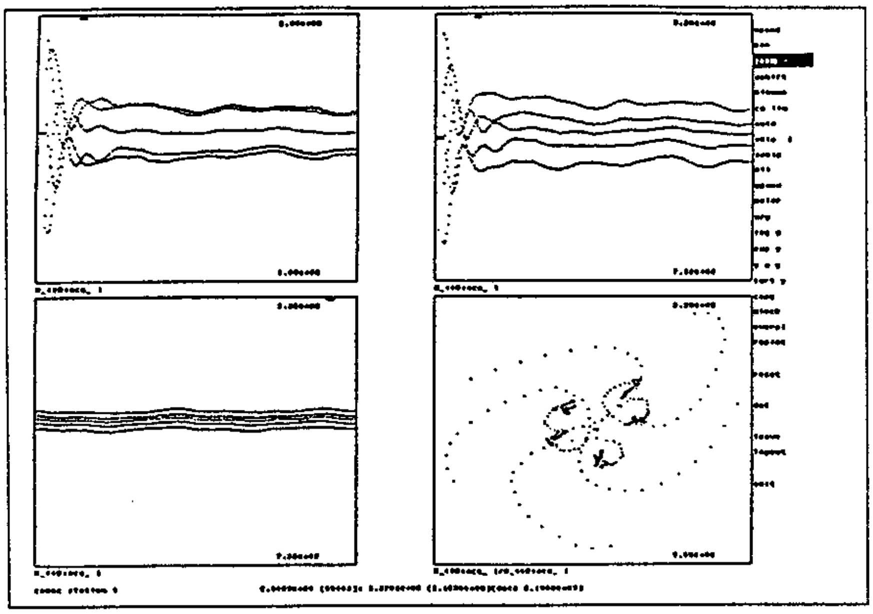

figure 3

REFERENCES

1. A. Chao et al, FN-471, January 1988
2. S. Peggs, SSC-N-261, November 1986